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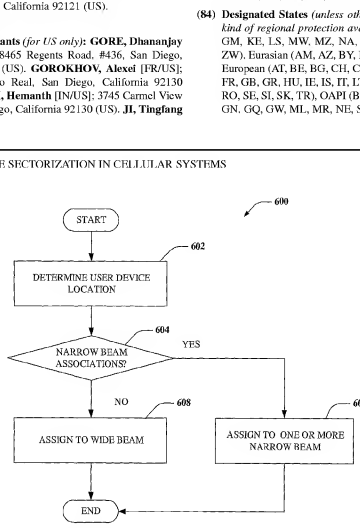
[Continued on next page]

(54) **Title:** ADAPTIVE SECTORIZATION IN CELLULAR SYSTEMS



(57) **Abstract:** Apparatuses and methodologies are described that enhance performance in a wireless communication system using beamforming transmissions. According to one aspect, a set of transmit beams are defined that simultaneously provides for space division multiplexing, multiple-input multiple output (MIMO transmission and opportunistic beamforming. The addition of a wide beam guarantees a minimum acceptable performance for all user devices.

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ADAPTIVE SECTORIZATION IN CELLULAR SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATION

Claim of Priority under 35 U.S.C. §119

1. The present Application for Patent claims priority to Provisional Application No. 60/691,716 filed June 16, 2005, and assigned to the assignee hereof and hereby expressly incorporated by reference herein.

Reference to Co-Pending Applications for Patent

2. The present Application for Patent is related to the following co-pending U.S. Patent Applications:

"CHANNEL QUALITY REPORTING FOR ADAPTIVE SECTORIZATION" having Attorney Docket No. 051010, filed concurrently herewith, assigned to the assignee hereof, and expressly incorporated by reference herein; and

"PRECODING AND SDMA SUPPORT" having Attorney Docket No. 051224, filed concurrently herewith, assigned to the assignee hereof, and expressly incorporated by reference herein.

"SDMA RESOURCE MANAGEMENT" having Attorney Docket No. 060031, filed concurrently herewith, assigned to the assignee hereof, and expressly incorporated by reference herein.

"Mobile Wireless Access System" having Attorney Docket No. 060081, filed concurrently herewith, assigned to the assignee hereof, and expressly incorporated by reference herein.

BACKGROUND

I. Field

[0001] The following description relates generally to wireless communications, and, amongst other things, to flexible communication schemes for wireless communication systems.

II. Background

[0002] Wireless networking systems have become a prevalent means by which a majority of people worldwide has come to communicate. Wireless communication devices have become smaller and more powerful in order to

meet eonsumer needs and to improve portability and convenience. Consumers have found many uses for wireless communication devices such as cellular telephones, personal digital assistants (PDAs) and the like, demanding reliable service and expanded areas of coverage.

[0003] Performance for a wireless communication system may be enhanced by using beamformed transmissions to communicate from the base station to the mobile devices. Multiple transmit antennas located at a base station can be used to form beamformed transmissions. Beamformed transmissions utilize "beams" that typieally cover a narrower area than transmissions using a single transmit antenna. However, the signal to interference and noise ratio (SINR) is enhanced within the area covered by the beams. The portions of a sector not covered by a beam are referred to as a null region. Mobile devices located within the null region will have will have an extremely low SINR, resulting in reduced performance and possible loss of data. The communication system may use beam steering, in which beams are dynamically directed at particular user devices. During beam steering, beams are redirected as user devices change location.

[0004] A typical wireless communication network (e.g., employing frequency, time, and eode division techniques) ineludes one or more base stations that provide a coverage area and one or more mobile (e.g., wireless) user devices that can transmit and receive data within the coverage area. A typical base station can simultaneously transmit multiple data streams for broadcast, multicast, and/or unicast services, wherein a data stream is a stream of data that can be of independent reception interest to a user deviee. A user device within the coverage area of that base station can be interested in receiving one, more than one or all the data streams carried by the eomposite stream. Likewise, a user device can transmit data to the base station or another user device. Such communication between base station and user device or between user devices can be degraded due to channel variations and/or interference power variations. For example, the aforementioned variations can affect base station scheduling, power control and/or rate prediction for one or more user deviees.

[0005] Conventional network fixed beamformed transmissions result in null regions, reducing network reliability, robustness and eoverage area. Thus, there

exists a need in the art for a system and/or methodology for improved beamformed transmission coverage.

SUMMARY

[0006] The following presents a simplified summary of one or more embodiments in order to provide a basic understanding of such embodiments. This summary is not an extensive overview of all contemplated embodiments, and is intended to neither identify key or critical elements of all embodiments nor delineate the scope of any or all embodiments. Its sole purpose is to present some concepts of one or more embodiments in a simplified form as a prelude to the more detailed description that is presented later.

[0007] In accordance with one or more embodiments and corresponding disclosure thereof, various aspects are described in connection with enhancing performance in a wireless communication system using beamforming transmissions. According to one aspect, a set of transmit beams are defined that simultaneously provides for space division multiplexing, multiple-input multiple output (MIMO) transmission and opportunistic beamforming. The addition of a wide beam guarantees a minimum acceptable performance for all user devices.

[0008] To that end, a method for enhancing performance of a wireless communications environment is described herein, wherein the method can comprise determining channel information for a user, and assigning a user deviee to at least one of a predetermined at least one narrow beam or a wide beam. Additionally, the method can comprise assigning another user device during a same time period to at least some overlapping frequencies and a different one of the at least one predetermined at least one narrow beam and a wide beam as the user device. Moreover, the at least one predetermined narrow beam can comprise a cluster of narrow beams and another cluster of narrow beams, wherein the eluster and the another cluster do not overlap. The method can also comprise modifying the direction of the at least one predetermined at least one narrow beam based upon a pattern of communication of the user device or reassigning the user device from the predetermined at least one narrow beam to the wide beam based upon a channel quality indicator.

[0009] According to another aspect, a wireless communication apparatus can comprise a memory that stores information related to at least one predetermined at least one narrow beam and at least one wide beam and a processor, coupled to the memory, that assigns a user device to at least one of the predetermined at least one narrow beam and the wide beam. The processor can schedule communications for the user device based upon a spatial division multiplexing, MIMO or opportunistic beamforming scheduling technique. Additionally, the processor can generate the wide beam using a cyclic delay diversity scheme and transmit broadcast control transmissions over the wide beam. Moreover, the apparatus can comprise a first cluster of antennas, a first cluster of narrow beams employs the first cluster of antennas, and a second cluster of antennas, a second cluster of narrow beams employs the second cluster of antennas, wherein the first and second clusters of narrow beams do not overlap.

[0010] According to yet another aspect, an apparatus for enhancing system performance in a wireless communication environment comprises means for generating a predetermined at least one narrow beam, means for generating a wide beam, and means for assigning a user device to at least one of the predetermined at least one narrow beam and the wide beam. Additionally, the apparatus can comprise means for scheduling communications for the user device based upon a spatial division multiplexing, MIMO or opportunistic beamforming scheduling technique.

[0011] Yet another aspect relates to a computer-readable medium having stored thereon computer-executable instructions for generating a predetermined at least one narrow beam, generating a wide beam, and assigning a user device to at least one of the predetermined at least one narrow beam and the wide beam. Moreover, the medium can comprise instructions for scheduling communications for the user device based upon a spatial division multiplexing, MIMO or opportunistic beamforming scheduling technique.

[0012] Still another aspect relates to a processor that executes instructions for enhancing system performance in a multiple access wireless communication environment, the instructions comprising generating a predetermined at least one narrow beam, generating a wide beam, and assigning a user device to at least one of the predetermined at least one narrow beam and the wide beam.

Additionally, the processor can execute instructions comprising scheduling communications for the user device based upon a spatial division multiplexing, MIMO or opportunistic beamforming scheduling technique.

[0013] A further aspect sets forth a mobile device that facilitates communicating over a wireless network, comprising a component that generates a predetermined at least one narrow beam, a component that generates a wide beam, and a component that assigns a user device to at least one of the predetermined at least one narrow beam and the wide beam.

[0014] To the accomplishment of the foregoing and related ends, the one or more embodiments comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative aspects of the one or more embodiments. These aspects are indicative, however, of but a few of the various ways in which the principles of various embodiments may be employed and the described embodiments are intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 illustrates a beam pattern for a wireless communication system in accordance with various embodiments presented herein.

[0016] FIG. 2 is an illustration of a wireless communication system according to one or more embodiments presented herein.

[0017] FIG. 3 is an illustration of a wireless communication system according to one or more embodiments presented herein.

[0018] FIG. 4 is an illustration of a beam pattern for a wireless communication system in accordance with various embodiments presented herein.

[0019] FIG. 5 is an illustration of a beam pattern for a wireless communication system in accordance with various embodiments presented herein.

[0020] FIG. 6 illustrates a methodology for assigning a user device to a transmit beam in accordance with one or more aspects presented herein.

[0021] FIG. 7 illustrates a methodology for assigning a user device to a transmit beam in accordance with one or more aspects presented herein.

[0022] FIG. 8 is an illustration of a system that utilizes beamforming to increase system capacity in a wireless communication environment in accordance with various aspects.

[0023] FIG. 9 is an illustration of a system that utilizes beamforming to increase system capacity in a wireless communication environment in accordance with various aspects.

[0024] FIG. 10 is an illustration of a wireless communication environment that can be employed in eonjunction with the various systems and methods described herein.

DETAILED DESCRIPTION

[0025] Various embodiments are now deseribed with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous speeific details are set forth in order to provide a thorough understanding of one or more embodiments. It may be evident, however, that such embodiment(s) may be practiced without these speeific details. In other instances, well-known struetures and devices are shown in bloek diagram form in order to facilitate deseribing one or more embodiments.

[0026] Furthermore, various embodiments are described herein in conneetion with a user device. A user device can also be called a system, a subscriber unit, subseriber station, mobile station, mobile device, remote station, aecess point, base station, remote terminal, aeeess terminal, user terminal, terminal, user agent, or user equipment. A user device can be a cellular telephone, a cordless telephone, a Session Initiation Protocol (SIP) phone, a wireless local loop (WLL) station, a PDA, a handheld communieations or computing device having wireless eonnection capability, a smartphone, a satellite radio, a global position system, a laptop, or other proeessing device eonnected to a wireless modem.

[0027] Moreover, various aspects or features described herein may be implemented as a method, apparatus, or article of manufacture using standard programming and/or engineering techniques. The term "article of manufacture" as used herein is intended to eneompass a computer program aceessible from any computer-readable device, carrier, or media. For example, computer readable media can

include but are not limited to magnetic storage devices (e.g., hard disk, floppy disk, magnetic strips...), optical disks (e.g., compact disk (CD), digital versatile disk (DVD)...), smart cards, and flash memory devices (e.g., card, stick, key drive...).

[0028] A wireless communication system can include one or more base stations in contact with one or more user devices. Each base station provides coverage for a plurality of sectors. In communication with a user device, the transmitting antennas of a base station can utilize beam-forming techniques in order to improve the signal-to-noise ratio of forward links for the different mobile devices. Forward link (or downlink) refers to the communication link from the base stations to mobile devices, and the reverse link (or uplink) refers to the communication link from mobile devices to the base stations. Additionally, a base station using beamforming to transmit to mobile devices scattered randomly through its coverage area causes less interference to mobile devices in neighboring cells/sectors than a base station transmitting through a single antenna to all mobile devices in its coverage area. Generally, beams generated by multiple transmit antennas are narrower than the coverage area of a single antenna. While user devices in the areas covered by beams experience an enhanced SINR, User devices within the null region experience a low SINR, possibly leading to loss of data. In general, user devices in the null region are worse off than if a single transmit antenna had been utilized to transmit performance.

[0029] While the disclosure discusses beamforming as a mode of operation, the disclosure and its contents may substantially be applied to precoded or beam-steered transmissions. This may be performed by, for example, utilizing fixed or predetermined matrices or vectors for which a user is scheduled.

[0030] Fig. 1 illustrates a beam pattern 100 for use in a wireless communication system in accordance with one or more embodiments presented herein. Base station transmit antennas can generate beams (e.g., a beam pattern) that can be employed to share time-frequency resources. The beam pattern can be adjusted from time to time, either periodically or based upon patterns of communication between the user devices and the base station. Multiple antennas at a base station 102 may assign a user on a first predetermined at least one narrow beam

104 or a second predetermined at least one narrow beam 106 for a sector 108. Narrow beam, as used herein, indicates that there is a dominant vector, or vectors in the case of a precoding or beam steering, for the transmission. The number of beams shown has been limited to two for the sake of simplicity. However, additional fixed beams may be generated. Beams may be generally orthogonal as illustrated in Fig. 1, or the coverage area of the beams may overlap. Users U1 and U2 are located within the coverage area of beams 106 and 104, respectively. Consequently, users U 1 and U2 experience an enhanced SINR, and/or other ehannel conditions similar to the benefits experienced by users in a beam-steering system. In contrast, users U3 and U4 will experience an extremely low SNR and/or other channel conditions since they are located within the null region of the beams 106 and 104. In fact, the performance for users U3 and U4 may be worse than if a single transmit antenna had been utilized.

[0031] The problems inherent in the use of narrow beams may be mitigated by generating another beam pattern that is not directed or direeted for the largest portion of the sector possible. In one or more embodiments, an additional wide beam 110 is generated. Wide beam 110 provides coverage for a substantial portion of the sector including the null region not covered by narrow beams 104 and 106. Wide beam 110 provides users U3 and U4 with a guaranteed minimum level of performance.

[0032] Referring now to Fig. 2, a wireless communieation system 200 in accordance with various embodiments presented herein is illustrated. System 200 can comprise one or more base stations 202 in one or more sectors that receive, transmit, repeat, etc., wireless communication signals to each other and/or to one or more mobile devices 204. Each base station 202 can comprise multiple transmitter ehains and receiver chains, e.g. one for each transmit and receive antenna, each of which can in turn comprise a plurality of components associated with signal transmission and reception (e.g., processors, modulators, multiplexers, demodulators, demultiplexers, antennas, ete.). Mobile devices 204 can be, for example, cellular phones, smart phones, laptops, handheld communication devices, handheld computing devices, satellite radios, global

positioning systems, PDAs, and/or any other suitable device for communicating over wireless system 200.

[0033] Referring now to Fig. 3, a multiple access wireless communication system 300 according to one or more embodiments is illustrated. A 3-sector base station 302 includes multiple antenna groups, one including antennas 304 and 306, another including antennas 308 and 310, and a third including antennas 312 and 314. According to the figure, only two antennas are shown for each antenna group, however, more or fewer antennas may be utilized for each antenna group. Typically, beamforming techniques require multiple transmit antennas to transmit beams. Mobile device 316 is in communication with antennas 312 and 314, where antennas 312 and 314 transmit information to mobile device 316 over forward link 320 and receive information from mobile device 316 over reverse link 318. Mobile device 322 is in communication with antennas 304 and 306, where antennas 304 and 306 transmit information to mobile device 322 over forward link 326 and receive information from mobile device 322 over reverse link 324.

[0034] Each group of antennas and/or the area in which they are designated to communicate may be referred to as a sector of base station 302. In one or more embodiments, antenna groups each are designed to communicate to mobile devices in a sector of the areas covered by base station 302. A base station may be a fixed station used for communicating with the terminals and may also be referred to as an access point, a Node B, or some other terminology. A mobile device may also be called a mobile station, user equipment (UE), a wireless communication device, terminal, access terminal, user device, or some other terminology.

[0035] Beamforming techniques can be used to provide fixed transmit directions in sectors or may be used in lieu of sectors. For example, beam patterns may provide multiple transmit directions in the sectors of a 3-sector base station, resulting in a virtual 6-sector base station. This ability to subdivide sectors results in increased system capacity.

[0036] Beamformed transmissions may be used with a number of different scheduling schemes, including space division multiplexing (SDM). SDM is a technique used in a multiple antenna communication system that utilizes the

spatial dimensions to support additional user devices for data transmissions. A space division multiple access system (SDMA) system relies on spatial signatures associated with each user device to schedule data transmissions from or to multiple user deviees and base stations. The spatial signature may be formed using the direction-of-arrival of the signal at the base station, the number of multipaths of the signal, and the attenuation of signal of each base station-mobile device pair or any other data that reflects the spatial relationship between the user device and base station. In a multiple antenna system, the spatial relationship between the base station and user device is determined based upon the signal received by the antennas at the base station. In this case, user device transmissions may be scheduled at the same time and on the same frequency on the beams and separated based upon a spatial signature. Through use of SDMA, disparate users can share time-frequency resourees while not being assoeiated with substantial cross talk.

[0037] Fixed beamforming patterns may also be used with MIMO and opportunistic beamforming scheduling techniques. In particular, user devices with well-conditioned matrix channels could be scheduled using MIMO. MIMO systems utilize multiple transmit and reeeive antennas to improve performanee. Multiple data streams corresponding to a single user device are scheduled at the same time and frequency on multiple beams, thereby increasing the data rate. In opportunistic beamforming, also referred to as beam selection, the base station transmits to a single user device over a given set of frequencies and time using a beam. No other beams are used for transmission to any other user over those frequencies and at those times.

[0038] SDM, MIMO and opportunistie beamforming ean be used with frequency division systems such as an orthogonal frequency division multiple access (OFDMA) system. An OFDMA system partitions the overall system bandwidth into multiple orthogonal subbands. These subbands are also referred to as tones, carriers, subcarriers, bins, and/or frequency channels. Each subband is associated with a subcarrier that can be modulated with data. An OFDMA system may use time and/or frequency division multiplexing to achieve orthogonality among multiple data transmissions for multiple user devices. Groups of user devices can be allocated separate subbands, and the data

transmission for each user device may be sent on the subband(s) allocated to this user device. SDMA, MIMO and opportunistic beamforming can be implemented for user device allocated to different frequency regions.

[0039] In a beamformed transmission system, beamforming techniques can be used to provide fixed transmit directions in sectors or may be used in lieu of sectors. For example, beam patterns may provide multiple transmit directions in the sectors of a 3-sector base station, resulting in a virtual 6-sector base station. This ability to subdivide sectors results in increased system capacity. User devices served by a base station sector can indicate a preference for a given beam. The base station may schedule transmission with the user device on the given beam using SDM, MIMO, opportunistic beamforming or any other scheduling method. In addition, beamforming with a fixed beam pattern allows a base station to utilize SDM, MIMO and opportunistic beamforming scheduling techniques simultaneously. For example, spatially orthogonal user devices may be scheduled using SDM, user devices with well-conditioned matrix channels could be scheduled using MIMO and additional users could be scheduled using opportunistic beamforming.

[0040] Systems utilizing fixed, narrow beams and the techniques discussed above can provide for enhanced throughput in a wireless communications environment. However, such systems lack robustness due to null regions. Looking once again at Fig. 1, user devices U1 and U2 are spatially orthogonal with disparate spatial signatures. Consequently, user device U1 and U2 would experience enhanced SINR using either SDM or opportunistic beamforming schemes. In contrast, user devices U3 and U4 will likely experience degraded SINR due to their location. Because both U3 and U4 are located within the null region, they will likely experience worse performance than if the system utilized a single transmit antenna.

[0041] Limited coverage areas of narrow beams may impact user device reliability and robustness. In general, user devices are designed to be mobile. Consequently, a user device may begin a transmission through utilization of a beam and may thereafter enter into a null region during transmission. Transmission within null regions may cause loss of data and decreased reliability. In addition, user devices may simply select the wrong beam. For

example, user device U1 may be desirably associated with a second beam 106. However, if user device U1 incorrectly elects transmissions over first beam 104 or if the user device U1 is incapable of electing a beam and is assigned to first beam 104 by the base station, the user device will experience the same performance as if the user device was located in the null region. Therefore, one or more user devices in a null region or otherwise having poor performance may be assigned to the wide beam. In addition, broadcast and control transmissions may be assigned to the wide beam.

[0042] The addition of a wide beam can ensure a minimum level of performance. The wide beam can be created using a transmission scheme that emulates a single antenna. For example, the wide beam may be generated using a cyclic delay diversity scheme. In general, the wide beam will have a low SINR gain compared to the narrow beams, but a significantly wider area of coverage than the narrow beams. User device can elect to be assigned to the wide beam. Consequently, the worst performance for any user device is limited to that of a single antenna transmission. Moreover, many user devices will experience enhanced performance in the narrow beam coverage areas. The base station can schedule user devices located in the narrow beam coverage areas using SDM, MIMO or beam selection methods or any combination thereof. The addition of the wide beam provides a guaranteed minimum level of robustness.

[0043] In addition, the system may utilize the wide beam to support broadcast control channels. Because the wide beam can be undirected or directed at a majority of the sector, the wide beam can be used to transmit to most or all of the user devices served by the sector simultaneously. Consequently, the base station does not have to transmit separate control transmissions for each narrow beam. A user device can be assigned to at least one of the narrow beam and the wide beam based upon type of data that is to be transmitted to the user device.

[0044] Referring now to Fig. 4, a beam pattern 400 utilizing multiple beams 402, 404 and 406 is illustrated. In one or more alternate embodiments, a base station can generate multiple narrow beams 402, 404 and 406 to effectively communicate with mobile stations in a sector, in addition to or instead of a wide beam. Use of multiple narrow beams, may not adequately mitigate when the user device selects the wrong beam. However, as long as the correct beam is

selected, user devices in the sector will experience enhanced performance. Beams 402, 404 and 406 can be either orthogonal or overlapping. As shown in Fig. 4, beams 402, 404 and 406 including their side lobes can be directed to effectively cover a sector.

[0045] In one or more embodiment, separate, fixed beams can be content specific. Fixed beams may be associated with specific, predictable directions for geographic areas or locations. Consequently, content specific to a particular location can be transmitted to user devices within the coverage area of a fixed beam associated with that location. For example, a mall can include a wireless communication system. Content specific to a first store at a first location in the mall may be transmitted using a first beam and content specific to a second store at a second location may be transmitted using a second beam. Consequently, user devices located at the first and second stores will receive transmissions specific to the store in which they are located. General mall information can be transmitted using a wide beam with a coverage area including the entire mall. Alternatively, narrow beams may be used to provide improved performance. For example, the wide beam may be used for general mall traffic, while a narrow beam may be directed at a first store having critical communication needs.

[0046] In one or more embodiments, beams are formed using a set of weights, that alter the phase, amplitude, or phase and amplitude of a particular transmission symbol or sample. These weights can be stored in a lookup table in memory. Beams can be updated by modifying the weights stored in the lookup table.

[0047] Referring now to Fig. 5, a beam pattern 500 for a sector 502 for a wireless communication system in accordance with various embodiments is illustrated. In general, SDMA, pre-coding and beamforming techniques are implemented using correlated antennas. However, uncorrelated antennas are preferable for MIMO transmissions and for receive antennas and in one or more embodiments, the same antennas may be utilized for both transmission and reception. To provide for MIMO, SDM and pre-coding simultaneously, a base station 504 can include two or more clusters of antennas. Antennas within each cluster are closely spaced. However, a larger distance separates the clusters of antennas. For example, separation of antennas within the cluster can be $\frac{1}{2}\lambda$, while separation between clusters can be 5λ. This antenna configuration provides the

diversity necessary for efficient MIMO and at the same time is sufficiently correlated for SDM, pre-coding, etc. The antenna configuration is capable of producing the beam pattern illustrated in Fig. 5. Here, clusters of beams 506 generate envelopes with the same effective beam pattern as the first and second beam shown in Fig. 1. The beam pattern illustrated in Fig. 5 can be used to support MIMO and SDMA simultaneously, thereby increasing the capacity of the system. It should be noted that in the case of precoding or beam steering, the directions show may be one direction or the dominant direction of the beam. The one or more narrow beams can each include a cluster of narrow beams and another cluster of narrow beams, wherein the clusters of narrow beams do not overlap.

[0048] Referring to Figs. 6-7, methodologies relating to increasing capacity in wireless communication systems are illustrated. For example, methodologies can relate to using beamforming in an SDMA environment, in an FDMA environment, an OFDMA environment, a CDMA environment, a WCDMA environment, a TDMA environment or any other suitable wireless environment. While, for purposes of simplicity of explanation, the methodologies are shown and described as a series of acts, it is to be understood and appreciated that the methodologies are not limited by the order of acts, as some acts may, in accordance with one or more embodiments, occur in different orders and/or concurrently with other acts from that shown and described herein. For example, those skilled in the art will understand and appreciate that a methodology could alternatively be represented as a series of interrelated states or events, such as in a state diagram. Moreover, not all illustrated acts may be utilized to implement a methodology in accordance with one or more embodiments.

[0049] Referring now to Fig. 6, a methodology 600 for assigning a user device to a beam in a wireless communication environment in accordance with one or more embodiments presented herein is illustrated. This methodology is described with respect to a system using one or more narrow beams in combination with a wide beam, wherein time-frequency resources can be shared between one or more of a set of narrow beams and the wide beam. At 602, the spatial relationship between the user device and the base station is determined. The

spatial relationship can be determined based upon the spatial signal of the base station-user device pair. Alternatively, the user device can include a global positioning system (GPS) capable of determining the location of the user device. At 604, it is determined whether the user device is to be associated with at least one narrow beam transmitted by the base station. If yes, the user device is assigned to the at least one narrow beam at 606. This assignment can be based upon information transmitted prior to the assignment, wherein the information is indicative of a predetermined at least one narrow beam and the wide beam. For instance, the information can comprise entries from a codebook. Moreover, the information can be quantized prior to transmitting such information. If no, the user device is assigned to the wide beam at 608. User devices can request specific beams or, alternatively, the base station can determine which user devices to assign to specific beams. In another example, a disparate user device can be to non-overlapping frequencies outside of the narrow beam or wide beam.

[0050] Referring now to Fig. 7, a methodology 700 for assigning a user device to a beam in a wireless communication environment in accordance with one or more embodiments presented herein is illustrated. At 702, a user device is assigned to at least one narrow beam. The channel quality indicator (CQI) (or other suitable channel quality information) for the user device is determined at 704. At 706, it is determined whether the CQI for user device is below a predetermined threshold. It should be noted that this threshold is determined by the CQI of the wide beam, or CQIs depending on the number of users assigned to the wide beam. As such, this threshold may vary over time as the CQI(s) of the user(s) assigned to the wide beam vary over time. Alternatively, a fixed threshold may also be utilized.

[0051] If no, the user device beam assignment remains unchanged at 708. If yes, the user device is assigned to the wide beam at 710. Alternatively, the quality of service (QoS) may be monitored to determine whether to switch a user device to the wide beam. The QoS, CQI, other channel information, or combinations thereof may be monitored just after the initial assignment or may be monitored periodically.

[0052] In general, user devices are capable of relocating or being relocated during voice or data transmission, thereby changing the spatial relationship between

user device and base station. Accordingly, a directed narrow beam may not be an optimal mode for sending and receiving communications. Therefore, user devices may be reassigned as they move through the sector. The veloeity of the user device can be monitored to determine whether the user device is moving in and out of the narrow beams so quickly that superior performance can be achieved by assigning the user device to the wide beam. In one or more embodiments, the user device can include an accelerometer. When the accelerometer indicates that the user device is moving quickly and therefore likely to move in and out of the narrow beam coverage area rapidly, the user device may be assigned to the wide beam, thereby avoiding repeated reassignment of the user device to multiple narrow beams.

[0053] It will be appreciated that, in accordance with one or more embodiments deseribed herein, inferences can be made regarding transmission formats, frequeneies, ete. As used herein, the term to "infer" or "inference" refers generally to the process of reasoning about or inferring states of the system, environment, and/or user from a set of observations as captured via events and/or data. Inference ean be employed to identify a specific context or aetion, or can generate a probability distribution over states, for example. The inference can be probabilistic–that is, the computation of a probability distribution over states of interest based on a consideration of data and events. Inference can also refer to techniques employed for composing higher-level events from a set of events and/or data. Sueh inference results in the construction of new events or actions from a set of observed events and/or stored event data, whether or not the events are correlated in close temporal proximity, and whether the events and data come from one or several event and data sources.

[0054] According to an example, one or methods presented above can include making inferences regarding a pattern of beams to allocate to a particular sector based upon the quality of service required in the sector. For example, it can be determined that high quality service is required in an area due to the critical nature of the communications to user devices in that area or simply due to the large number of user devices or customers in an area.

[0055] According to another example, inferences can be made relating to a beam pattern to employ during various times of the day, week, etc., such as peak hours

and the like. It will be appreciated that the foregoing examples are illustrative in nature and are not intended to limit the number of inferences that can be made or the manner in which such inferences are made in conjunction with the various embodiments and /or methods described herein.

[0056] Fig. 8 is an illustration of a system 800 that facilitates beamforming in a wireless communication environment to increase system capacity limits in accordance with one or more embodiments set forth herein. System 800 can reside in a base station and/or in a user device, as will be appreeiated by one skilled in the art. System 800 comprises a receiver 802 that receives a signal and from, for instance one or more receive antennas, and performs typical actions thereon (e.g., filters, amplifies, downconverts, etc.) the received signal and digitizes the conditioned signal to obtain samples. A demodulator 804 can demodulate and provide received pilot symbols to a processor 806 for channel estimation.

[0057] Processor 806 can be a processor dedicated to analyzing information received by receiver component 802 and/or generating information for transmission by a transmitter 814. Processor 806 ean be a processor that controls one or more components of user device 800, and/or a processor that analyzes information received by receiver 802, generates information for transmission by a transmitter 814, and controls one or more components of user device 800. User device 800 can include an optimization component 808 that coordinates beam assignments. Optimization component 808 may be incorporated into the processor 806. It is to be appreciated that optimization component 808 can include optimization code that performs utility based analysis in connection with assigning user devices to beams. The optimization eode can utilize artificial intelligence based methods in connection with performing inference and/or probabilistic determinations and/or statistieal-based determinations in connection with optimizing user device beam assignments.

[0058] User device 800 can additionally comprise memory 810 that is operatively coupled to processor 806 and that stores information related to beam pattern information, lookup tables comprising information related thereto, and any other suitable information related to beamforming as described herein. Memory 810 can additionally store protocols associated with generating lookup tables, etc.,

such that user device 800 can employ stored protocols and/or algorithms to increase system capacity. It will be appreciated that the data store (e.g., memories) components described herein can be either volatile memory or nonvolatile memory, or can include both volatile and nonvolatile memory. By way of illustration, and not limitation, nonvolatile memory can include read only memory (ROM), programmable ROM (PROM), electrically programmable ROM (EPROM), electrically erasable ROM (EEPROM), or flash memory. Volatile memory can include random access memory (RAM), which acts as external cache memory. By way of illustration and not limitation, RAM is available in many forms such as synchronous RAM (SRAM), dynamic RAM (DRAM), synchronous DRAM (SDRAM), double data rate SDRAM (DDR SDRAM), enhanced SDRAM (ESDRAM), Synchlink DRAM (SLDRAM), and direct Rambus RAM (DRRAM). The memory 810 of the subject systems and methods is intended to comprise, without being limited to, these and any other suitable types of memory. The processor 806 is connected to a symbol modulator 812 and transmitter 814 that transmits the modulated signal.

[0059] Fig. 9 is an illustration of a system 900 that facilitates increasing system capacity in a communication environment in accordance with various embodiments. System 900 comprises a base station 902 with a receiver 910 that receives signal(s) from one or more user devices 904 via one or more receive antennas 906, and transmits to the one or more user devices 904 through a plurality of transmit antennas 908. In one or more embodiments, receive antennas 906 and transmit antennas 908 can be implemented using a single set of antennas. Receiver 910 can receive information from receive antennas 906 and is operatively associated with a demodulator 912 that demodulates received information. Receiver 910 can be, for example, a Rake receiver (e.g., a technique that individually processes multi-path signal components using a plurality of baseband correlators, ...), an MMSE-based receiver, or some other suitable receiver for separating out user devices assigned thereto, as will be appreciated by one skilled in the art. According to various aspects, multiple receivers can be employed (e.g., one per receive antenna), and such receivers can communicate with each other to provide improved estimates of user data. Demodulated symbols are analyzed by a processor 914 that is similar to the

processor described above with regard to Fig. 8, and is coupled to a memory 916 that stores information related to user device assignments, lookup tables related thereto and the like. Receiver output for each antenna ean be jointly processed by receiver 910 and/or processor 914. A modulator 918 can multiplex the signal for transmission by a transmitter 920 through transmit antennas 908 to user devices 904.

[0060] Base station 902 further comprises an assignment component 922, which can be a processor distinct from or integral to processor 914, and which can evaluate a pool of all user devices in a sector served by base station 904 and can assign user devices to beams based at least in part upon the location of the individual user devices.

[0061] Fig. 10 shows an exemplary wireless communication system 1000. The wireless communication system 1000 depicts one base station and one user device for sake of brevity. However, it is to be appreciated that the system can include more than one base station and/or more than one user device, wherein additional base stations and/or user devices can be substantially similar or different from the exemplary base station and user device described below. In addition, it is to be appreeiated that the base station and/or the user device can employ the systems (Figs. 8-9) and/or methods (Figs. 6-7) described herein to facilitate wireless communication there between.

[0062] Referring now to Fig. 10, on a downlink, at access point 1005, a transmit (TX) data processor 1010 receives, formats, codes, interleaves, and modulates (or symbol maps) traffic data and provides modulation symbols ("data symbols"). A symbol modulator 1015 receives and processes the data symbols and pilot symbols and provides a stream of symbols. Symbol modulator 1015 multiplexes data and pilot symbols and provides them to a transmitter unit (TMTR) 1020. Each transmit symbol may be a data symbol, a pilot symbol, or a signal value of zero. The pilot symbols may be sent continuously in each symbol period. The pilot symbols can be frequency division multiplexed (FDM), orthogonal frequency division multiplexed (OFDM), time division multiplexed (TDM), frequency division multiplexed (FDM), or code division multiplexed (CDM).

[0063] TMTR 1020 receives and converts the stream of symbols into one or more analog signals and further conditions (e.g., amplifies, filters, and frequency upconverts) the analog signals to generate a downlink signal suitable for transmission over the wireless channel. The downlink signal is then transmitted through an antenna 1025 to the user devices. At user device 1030, an antenna 1035 receives the downlink signal and provides a received signal to a receiver unit (RCVR) 1040. Receiver unit 1040 conditions (e.g., filters, amplifies, and frequency downconverts) the received signal and digitizes the conditioned signal to obtain samples. A symbol demodulator 1045 demodulates and provides received pilot symbols to a processor 1050 for channel estimation. Symbol demodulator 1045 further receives a frequency response estimate for the downlink from processor 1050, performs data demodulation on the received data symbols to obtain data symbol estimates (which are estimates of the transmitted data symbols), and provides the data symbol estimates to an RX data processor 1055, which demodulates (i.e., symbol demaps), deinterleaves, and decodes the data symbol estimates to recover the transmitted traffic data. The processing by symbol demodulator 1045 and RX data processor 1055 is complementary to the processing by symbol modulator 1015 and TX data processor 1010, respectively, at access point 1005.

[0064] On the uplink, a TX data processor 1060 processes traffic data and provides data symbols. A symbol modulator 1065 receives and multiplexes the data symbols with pilot symbols, performs modulation, and provides a stream of symbols. A transmitter unit 1070 then receives and processes the stream of symbols to generate an uplink signal, which is transmitted by the antenna 1035 to the access point 1005.

[0065] At access point 1005, the uplink signal from user device 1030 is received by the antenna 1025 and processed by a receiver unit 1075 to obtain samples. A symbol demodulator 1080 then processes the samples and provides received pilot symbols and data symbol estimates for the uplink. An RX data processor 1085 processes the data symbol estimates to recover the traffic data transmitted by user device 1030. A processor 1090 performs channel estimation for each active user device transmitting on the uplink. Multiple user devices may

transmit pilot concurrently on the uplink on their respective assigned sets of pilot subbands, where the pilot subband sets may be interlaced.

[0066] Processors 1090 and 1050 direct (e.g., control, coordinate, manage, etc.) operation at access point 1005 and user device 1030, respectively. Respective processors 1090 and 1050 can be associated with memory units (not shown) that store program codes and data. Processors 1090 and 1050 can also perform computations to derive frequency and impulse response estimates for the uplink and downlink, respectively.

[0067] For a multiple-access system (e.g., FDMA, OFDMA, CDMA, TDMA, SDMA, etc.), multiple user devices can transmit concurrently on the uplink. For such a system, the pilot subbands may be shared among different user devices. The channel estimation techniques may be used in cases where the pilot subbands for each user device span the entire operating band (possibly except for the band edges). Such a pilot subband structure would be desirable to obtain frequency diversity for each user device. The techniques described herein may be implemented by various means. For example, these techniques may be implemented in hardware, software, or a combination thereof. For a hardware implementation, the processing units used for channel estimation may be implemented within one or more application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof. With software, implementation can be through modules (e.g., procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in memory unit and executed by the processors 1090 and 1050.

[0068] For a software implementation, the techniques described herein may be implemented with modules (e.g., procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in memory units and executed by processors. The memory unit may be implemented within the processor or external to the processor, in which case it can be

communicatively coupled to the processor via various means as is known in the art.

[0069] What has been described above includes examples of one or more embodiments. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the aforementioned embodiments, but one of ordinary skill in the art may recognize that many further combinations and permutations of various embodiments are possible. Accordingly, the described embodiments are intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims. Furthermore, to the extent that the term "includes" is used in either the detailed description or the claims, such term is intended to be inclusive in a manner similar to the term "comprising" as "comprising" is interpreted when employed as a transitional word in a claim.

CLAIMS

What is claimed is:

1. A method for enhancing performance for a wireless communication environment, comprising:

determining channel information for a user; and

assigning a user device to at least one of a predetermined at least one narrow beam or a wide beam.

2. The method of claim 1, further comprising assigning another user device to during a same time period to at least some overlapping frequencies and a different of the at least one predetermined at least one narrow beam and wide beam as the user device.

3. The method of claim 1, wherein the at least one predetermined at least one narrow beam comprises a cluster of narrow beams and another cluster of narrow beams, wherein the cluster and the another cluster do not overlap.

4. The method of claim 1, further comprising generating the wide beam using a cyclic delay diversity scheme.

5. The method of claim 1, further comprising assigning broadcast control transmissions to one or more user devices to the wide beam.

6. The method of claim 1, further comprising modifying the direetion of the at least one predetermined at least one narrow beam based upon a pattern of communication of the user device.

7. The method of claim 1, further comprising reassigning the user device from the predetermined at least one narrow beam to the wide beam based upon channel quality information.

8. The method of claim 7, the channel quality information is the signal to interference and noise ratio.

9. The method of claim 1, further comprising assigning the user device to the wide beam based upon a determined velocity of the user device.

10. The method of claim 1, wherein assigning the user device comprises assigning the user device based at least in part upon a selection by the user device of the at least one of the predetermined at least one narrow beam or the wide beam.

11. The method of claim 1, wherein assigning the user device comprises assigning the user device based at least in part upon a quality of service indicated for the user device.

12. The method of claim 1, wherein assigning the user device comprises assigning the user device based at least in part upon a type of data to be transmitted to the user device.

13. The method of claim 1, wherein the at least one predetermined at least one narrow beam comprises a cluster of narrow beams and another cluster of narrow beams, wherein at least some of the cluster and the another cluster overlap.

14. The method of claim 1, further comprising assigning another user device to during a same time period to non-overlapping frequencies without the at least one predetermined at least one narrow beam or wide beam.

15. The method of claim 1, further comprising, prior to assigning, transmitting information indicative of the at least one of the predetermined at least one narrow beam and the wide beam.

16. The method of claim 15, wherein the information comprises entries from a codebook.

17. The method of claim 15, further comprising quantizing the information indicative prior to transmitting.

18. A wireless communication apparatus, comprising:

a memory that stores information related to at least one predetermined at least one narrow beam and wide beam; and

a processor, coupled to the memory, that assigns a user device to at least one of the predetermined at least one narrow beam and the wide beam.

19. The apparatus of claim 18, the processor schedules communications for the user device based upon a spatial division multiplexing, multiple input multiple output (MIMO) or opportunistic beamforming scheduling technique.

20. The apparatus of claim 19, further comprising:

a first cluster of antennas, a first cluster of narrow beams employs the first cluster of antennas; and

a second cluster of antennas, a second cluster of narrow beams utilizes the second cluster of antennas, the first and second cluster of narrow beams do not overlap.

21. The apparatus of claim 18, the processor generates the wide beam using a cyclic delay diversity scheme.

22. The apparatus of claim 18, the processor transmits broadcast control transmissions over the wide beam.

23. The apparatus of claim 18, the processor modifies the direction of the predetermined narrow beam based upon a pattern of communication of the user device.

24. The apparatus of claim 18, the processor reassigns the user device from the predetermined at least one narrow beam to the wide beam based upon a channel quality indicator.

25. The apparatus of claim 24, the channel quality indicator is the signal to interference and noise ratio.

26. The apparatus of claim 18, the processor assigns the user device to the wide beam based upon a velocity of the user device.

27. The apparatus of claim 18, the user device indicates a preference for at least one of the predetermined at least one narrow beam or the wide beam.

28. An apparatus for enhancing performance for a wireless communication environment, comprising:

means for generating at least one predetermined narrow beam;

means for generating a wide beam; and

means for assigning a user device to at least one of the at least one predetermined narrow beam and the wide beam.

29. The apparatus of claim 28, further comprising means for scheduling communications for the user device based upon a spatial division multiplexing, multiple input multiple output (MIMO) or opportunistic beamforming scheduling technique.

30. The apparatus of claim 28, further comprising means for modifying the direction of the at least one predetermined narrow beam based upon a pattern of communication of the user device.

31. The apparatus of claim 28, further comprising means for reassigning the user device from the at least one predetermined narrow beam to the wide beam based upon a channel quality indicator.

32. The apparatus of claim 28, further comprising means for assigning the user device to the wide beam based upon the velocity of the user device.

33. The apparatus of claim 28, further comprising means for indicating a preference for at least one of the at least one predetermined narrow beam or the wide beam for the user device.

34. A computer-readable medium having stored thereon computer-executable instructions for:

generating a at least one predetermined narrow beam;

generating a wide beam; and

assigning a user device to at least one of the at least one predetermined narrow beam and the wide beam.

35. The computer-readable medium of claim 34, further comprising instructions for scheduling communications for the user device based upon a spatial division multiplexing, multiple input multiple output (MIMO) or opportunistic beamforming scheduling technique.

36. The computer-readable medium of claim 34, further comprising instructions for generating the wide beam using a cyclic delay diversity scheme.

37. The computer-readable medium of claim 34, further comprising instructions for transmitting broadcast control transmissions over the wide beam.

38. The computer-readable medium of claim 34, further comprising instructions for modifying the direction of the predetermined narrow beam based upon a pattern of communication of the user device.

39. The computer-readable medium of claim 34, further comprising instructions for reassigning the user device from the predetermined narrow beam to the wide beam based upon a channel quality indicator.

40. The computer-readable medium of claim 34, further comprising instructions for assigning the user device to the wide beam based upon a velocity of the user device.

41. A processor that exeeutes instructions for enhancing performance for a wireless communication environment, the instructions comprising:

generating a at least one predetermined narrow beam;

generating a wide beam; and

assigning a user deviee to at least one of the at least one predetermined narrow beam and the wide beam.

42. The processor of claim 41, the instructions further eomprising scheduling communications for the user device based upon a spatial division multiplexing, multiple input multiple output (MIMO) or opportunistic beamforming scheduling technique.

43. A mobile device that faeilitates communicating over a wireless network, comprising:

a component configured to request assignment of the mobile device to at least one of at least one predetermined narrow beam and the wide beam; and

a transmitter that transmits the request to a base station.

44. The mobile device of claim 43, the device is at least one of a cellular phone, a smartphone, a handheld communication device, a handheld computing device, a satellite radio, a global positioning system, a laptop, and a PDA.

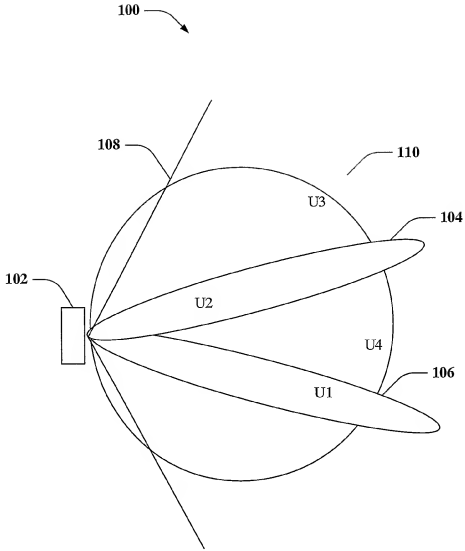


FIG. 1

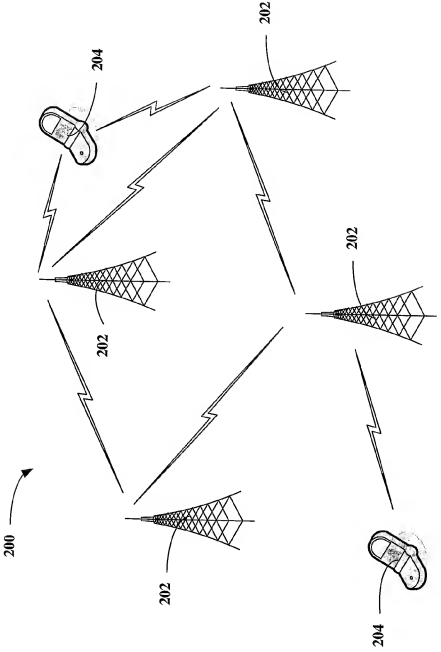


FIG. 2

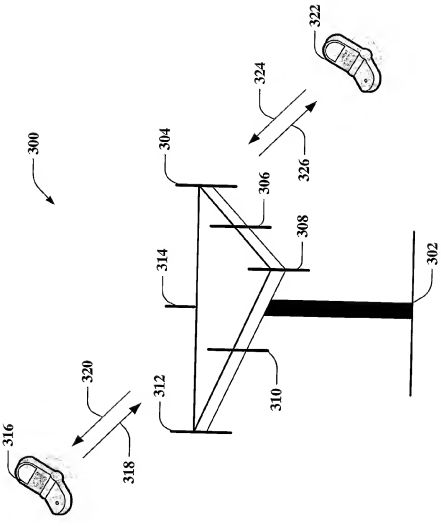


FIG. 3

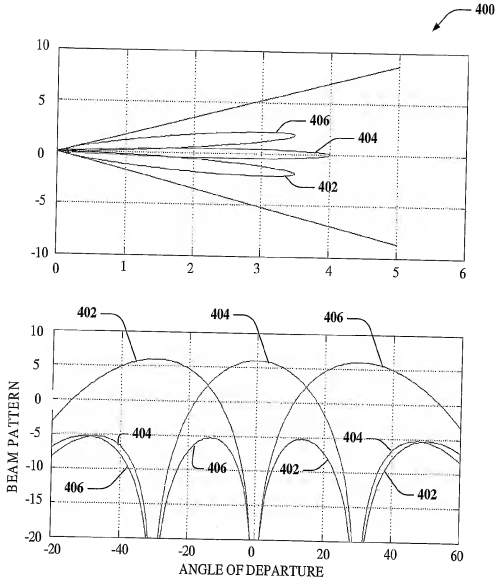

400
10
5
0
-5
-10
0
1
2
3
4
5
6
406
404
402
402
404
406
BEAM PATTERN
10
5
0
-5
-10
-15
-20
-20
-40
-20
0
20
40
60
ANGLE OF DEPARTURE
404
406
406
402
404
402

FIG. 4

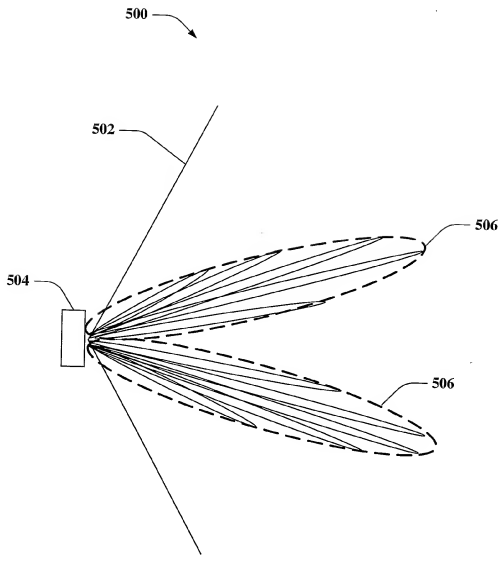


FIG. 5

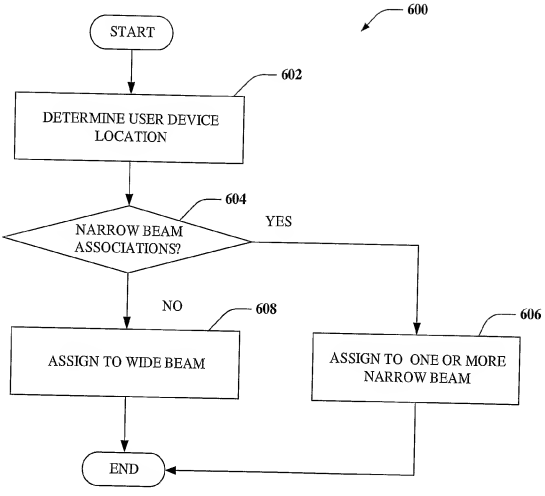
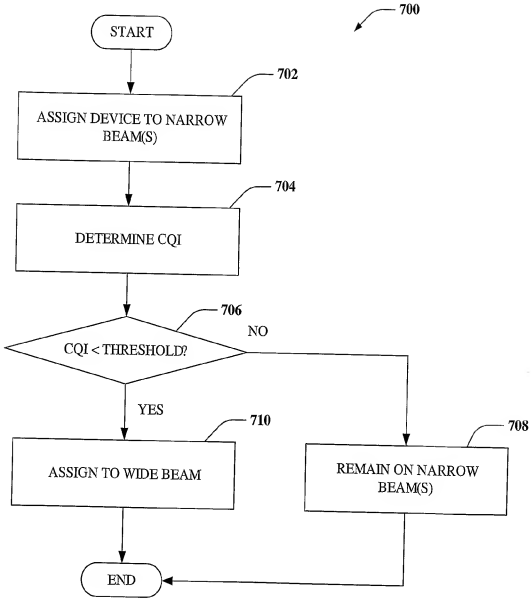

600
START
602
DETERMINE USER DEVICE LOCATION
604
NARROW BEAM ASSOCIATIONS?
YES
NO
608
ASSIGN TO WIDE BEAM
606
ASSIGN TO ONE OR MORE NARROW BEAM
END

FIG. 6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START
702
ASSIGN DEVICE TO NARROW BEAM(S)
704
DETERMINE CQI
706
CQI < THRESHOLD?
NO
YES
710
ASSIGN TO WIDE BEAM
708
REMAIN ON NARROW BEAM(S)
END

FIG. 7

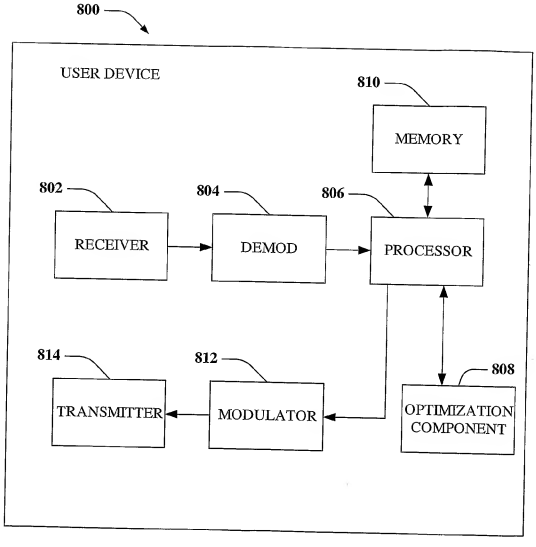
800
USER DEVICE
810
MEMORY
802
804
806
RECEIVER
DEMOD
PROCESSOR
814
812
808
TRANSMITTER
MODULATOR
OPTIMIZATION COMPONENT

FIG. 8

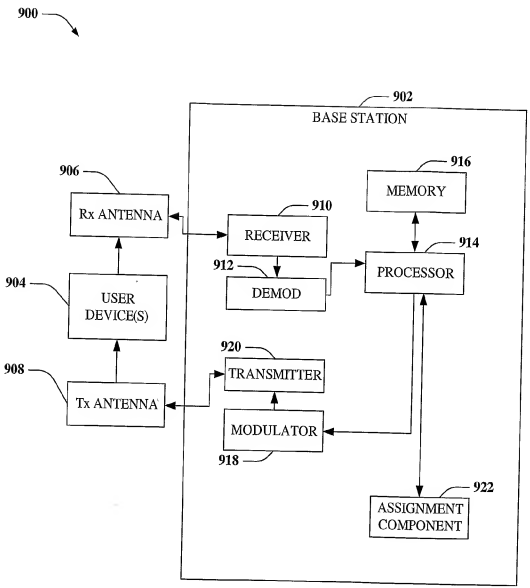
900
902
BASE STATION
906
Rx ANTENNA
910
RECEIVER
916
MEMORY
914
PROCESSOR
912
DEMOD
904
USER
DEVICE(S)
920
TRANSMITTER
908
Tx ANTENNA
MODULATOR
918
922
ASSIGNMENT
COMPONENT

FIG. 9

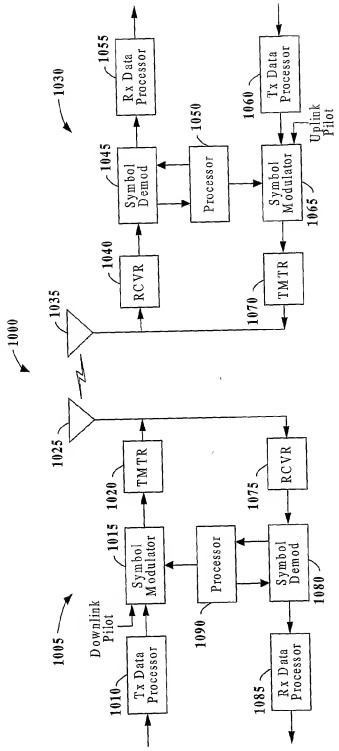
1000
1005
Downlink Pilot
1010
Tx Data Processor
1015
Symbol Modulator
1020
TMTR
1025
1030
1035
1040
RCVR
1045
Symbol Demod
1050
Processor
1055
Rx Data Processor
1060
Tx Data Processor
Uplink Pilot
1065
Symbol Modulator
1070
TMTR
1075
RCVR
1080
Symbol Demod
1085
Rx Data Processor
1090
Processor

FIG. 10